
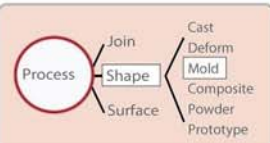


Browse **Select** Search Print Search web

Choose data-table:
materials, processes ...

New ▼

- Graph stage → 
- Limit stage →

	Min	Max
Density	<input type="text"/>	2
Modulus	200	<input type="text"/>
Strength	100	<input type="text"/>
T-conduction	<input type="text"/>	10
- Tree stage → 

GRANTA | CES 2007
EDUPACK

1 Getting Started with CES EduPack

Getting started with CES EduPack

These exercises give an easy way to learn to use the CES EduPack software. The comprehensive Help file and CES InDepth within the software give more detailed guidance.

Thumbnail sketch of CES EduPack

The CES EduPack software has three Levels of Database.

	Coverage	Content
Level 1	65 of the most widely used materials drawn from the classes: metals, polymers, ceramics, composites, foams and natural materials. 75 of the most widely used processes	A description, an image of the material in a familiar product, typical applications and limited data for mechanical, thermal and electrical properties, using rankings where appropriate.
Level 2	95 of the most widely used materials. 105 of the most commonly used processes	All the content of Level 1, supplemented by more extensive numerical data, design guidelines, ecological properties and technical notes.
Level 3	The core database contains more than 3,000 materials, including those in Levels 1 and 2. Also available are optional CAMPUS and MIL Handbooks databases.	Extensive numerical data for all materials, allowing the full power of the CES selection system to be deployed.

When the software opens you are asked to choose a Level. Chose Level 1 to start with.

At each Level there are a number of Data Tables.

The most important are: Materials, Shaping Processes, Joining Processes, and Surface Treatments.

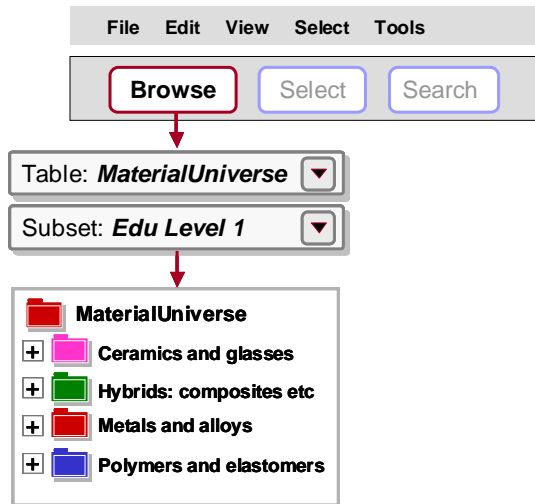
Each of the three levels can be interrogated by

- **BROWSING** Exploring the database and retrieving records via a hierarchical index.
- **SEARCHING** Finding information via a full-text search of records.
- **SELECTION** Use of powerful selection engine to find records that meet an array of design criteria.

The CES EduPack does far more than this. But this is enough to get started.

BROWSING and SEARCHING

The DEFAULT on loading CES EduPack Levels 1 & 2 is LEVEL 1, MATERIALS UNIVERSE



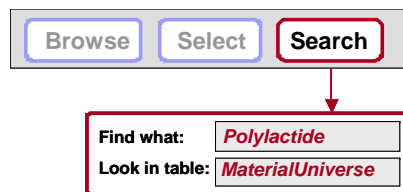
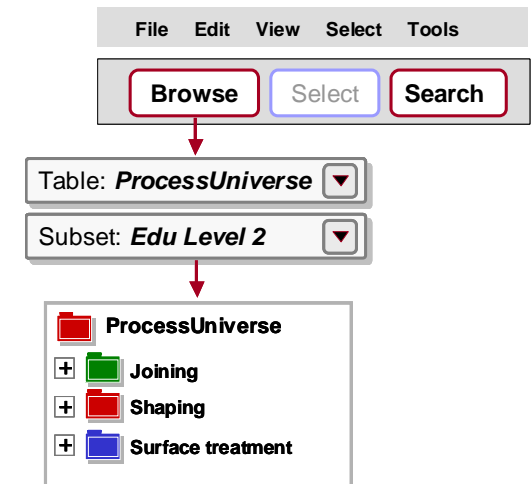
Exercise 1. BROWSE materials

- Find record for STAINLESS STEEL
- Find record for CONCRETE
- Find record for POLYPROPYLENE
- Explore POLYPROPYLENE record at LEVEL 2
- Find PROCESSES that can shape POLYPROPYLENE using the LINK at the bottom of the record

Exercise 2. BROWSE processes

Select LEVEL 2, ALL PROCESSES

- Find record for INJECTION MOLDING
- Find record for LASER SURFACE HARDENING
- Find record for FRICTION WELDING (METALS)
- Find MATERIALS that can be DIE CAST, using the LINK at the bottom of the record for DIE CASTING



Exercise 3. The SEARCH facility

- Find the material POLYLACTIDE
- Find materials for CUTTING TOOLS
- Find the process RTM

(Part of a material record and a process record are shown overleaf)

Part of a record for a material: polypropylene

Polypropylene (PP) (CH₂-CH(CH₃))_n

Polypropylene, PP, first produced commercially in 1958, is the younger brother of polyethylene - a very similar molecule with similar price, processing methods and application. Like PE it is produced in very large quantities (more than 30 million tons per year in 2000), growing at nearly 10% per year, and like PE its molecule-lengths and side-branches can be tailored by clever catalysis, giving precise control of impact strength, and of the properties that influence molding and drawing. In its pure form polypropylene is flammable and degrades in sunlight. Fire retardants make it slow to burn and stabilizers give it extreme stability, both to UV radiation and to fresh and salt water and most aqueous solutions.



General properties

Density	0.89	-	0.91	Mg/m ³
Price	1.102	-	1.61	USD/kg

Mechanical properties

Young's Modulus	0.896	-	1.55	GPa
Shear Modulus	0.31	-	0.54	GPa
Bulk modulus	2.5	-	2.6	GPa
Poisson's Ratio	0.40	-	0.42	
Hardness - Vickers	6.2	-	11.2	HV
Elastic Limit	20.7	-	37.2	MPa
Tensile Str ength	27.6	-	41.4	MPa
Compressive Strength	25.1	-	55.2	MPa
Elongation	100	-	600	%
Endurance Limit	11.0	-	16.5	MPa
Fracture Toughness	3	-	4.5	MPa.m ^{1/2}
Loss Coefficient	0.025	-	0.044	

Thermal properties

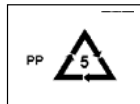
Thermal conductor or insulator?	Good insulator		
Thermal Conductivity	0.113	- 0.167	W/m.K
Thermal Expansion	122.4	- 180	µstrain/K
Specific Heat	1870	- 1956	J/kg.K
Melting Point	149.9	- 174.9	°C
Glass Temperature	-25.15	- -15.15	°C
Maximum Service Temperature	82.85	- 106.9	°C
Minimum Service Temperature	-123.2	- -73.15	°C

Electrical properties

Electrical conductor or insulator?	Good insulator		
Resistivity	3.3e22	- 3e23	µohm.cm
Dielectric Constant	2.2	- 2.3	
Power Factor	5e-4	- 7e-4	
Breakdown Potential	22.7	- 24.6	1000000*V/m

Design guidelines

Standard grade PP is inexpensive, light and ductile but it has low strength. It is more rigid than PE and can be used at higher temperatures. The properties of PP are similar to those of HDPE but it is stiffer and melts at a higher temperature (165 - 170 C). Stiffness and strength can be improved further by reinforcing with glass, chalk or talc. When drawn to fiber PP has exceptional strength and resilience; this, together with its resistance to water, makes it attractive for ropes and fabric. It is more easily molded than PE, has good transparency and can accept a wider, more vivid range of colors. PP is commonly produced as sheet, moldings fibers or it can be foamed. Advances in catalysis promise new co-polymers of PP with more attractive combinations of toughness, stability and ease of processing. Mono-filaments fibers have high abrasion resistance and are almost twice as strong as PE fibers. Multi-filament yarn or rope does not absorb water, will float on water and dyes easily.



Technical notes

The many different grades of polypropylene fall into three basic groups: homopolymers (polypropylene, with a range of molecular weights and thus properties), co-polymers (made by co-Polymerization of propylene with other olefines such as ethylene, butylene or styrene) and composites (polypropylene reinforced with mica, talc, glass powder or fibers) that are stiffer and better able to resist heat than simple polypropylenes.

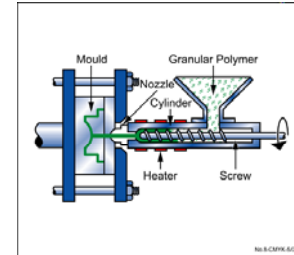
Typical uses

Ropes, general polymer engineering, automobile air ducting, parcel shelving and air-cleaners, garden furniture, washing machine tank, wet-cell battery cases, pipes and pipe fittings, beer bottle crates, chair shells, capacitor dielectrics, cable insulation, kitchen kettles, car bumpers, shatter proof glasses, crates, suitcases, artificial turf.

Part of a record for a process: injection molding

Injection molding

No other process has changed product design more than injection molding. Injection molded products appear in every sector of product design: consumer products, business, industrial, computers, communication, medical and research products, toys, cosmetic packaging and sports equipment. The most common equipment for molding thermoplastics is the reciprocating screw machine, shown schematically in the figure. Polymer granules are fed into a spiral press where they mix and soften to a dough-like consistency that can be forced through one or more channels ('sprues') into the die. The polymer solidifies under pressure and the component is then ejected.



Thermoplastics, thermosets and elastomers can all be injection molded. Co-injection allows molding of components with different materials, colors and features. Injection foam molding allows economical production of large molded components by using inert gas or chemical blowing agents to make components that have a solid skin and a cellular inner structure.

Physical Attributes

Mass range	0.01	-	25	kg
Range of section thickness	0.4	-	6.3	mm
Tolerance	0.2	-	1	mm
Roughness	0.2	-	1.6	µm
Surface roughness (A=v. smooth)	A			

Shape

Circular Prismatic	True
Non-circular Prismatic	True
Solid 3-D	True
Hollow 3-D	True

Economic Attributes

Economic batch size (units)	1e4	-	1e6
Relative tooling cost	very high		
Relative equipment cost	high		
Labor intensity	low		

Design guidelines

Injection molding is the best way to mass-produce small, precise, polymer components with complex shapes. The surface finish is good; texture and pattern can be easily altered in the tool, and fine detail reproduces well. Decorative labels can be molded onto the surface of the component (see In-mould Decoration). The only finishing operation is the removal of the sprue.

Technical notes

Most thermoplastics can be injection molded, although those with high melting temperatures (e.g. PTFE) are difficult. Thermoplastic based composites (short fiber and particulate filled) can be processed providing the filler-loading is not too large. Large changes in section area are not recommended. Small re-entrant angles and complex shapes are possible, though some features (e.g. undercuts, screw threads, inserts) may result in increased tooling costs. The process may also be used with thermosets and elastomers. The most common equipment for molding thermoplastics is the reciprocating screw machine, shown schematically in the figure. Polymer granules are fed into a spiral press where they mix and soften to a dough-like consistency that can be forced through one or more channels ('sprues') into the die. The polymer solidifies under pressure and the component is then ejected.

Typical uses

Extremely varied. Housings, containers, covers, knobs, tool handles, plumbing fittings, lenses, etc.

The economics

Capital cost are medium to high, tooling costs are usually high - making injection molding economic only for large batch sizes. Production rate can be high particularly for small moldings. Multi-cavity moulds are often used. Prototype moldings can be made using single cavity moulds of cheaper materials.

PROPERTY CHARTS

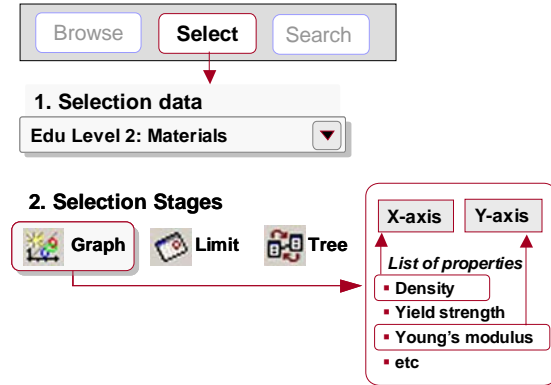
Exercise 4. Making PROPERTY CHARTS

- Make a BAR CHART of YOUNG’S MODULUS (E)

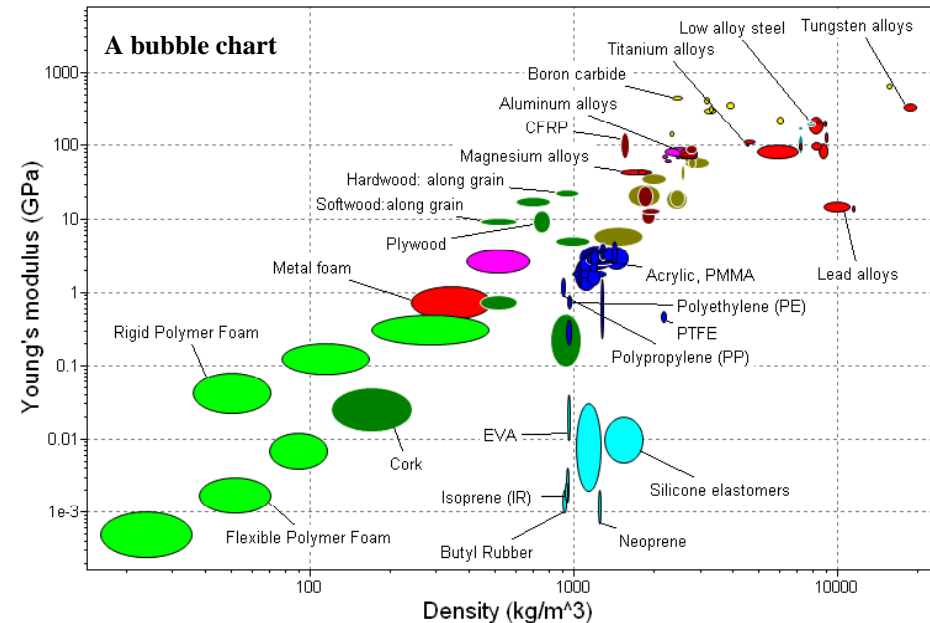
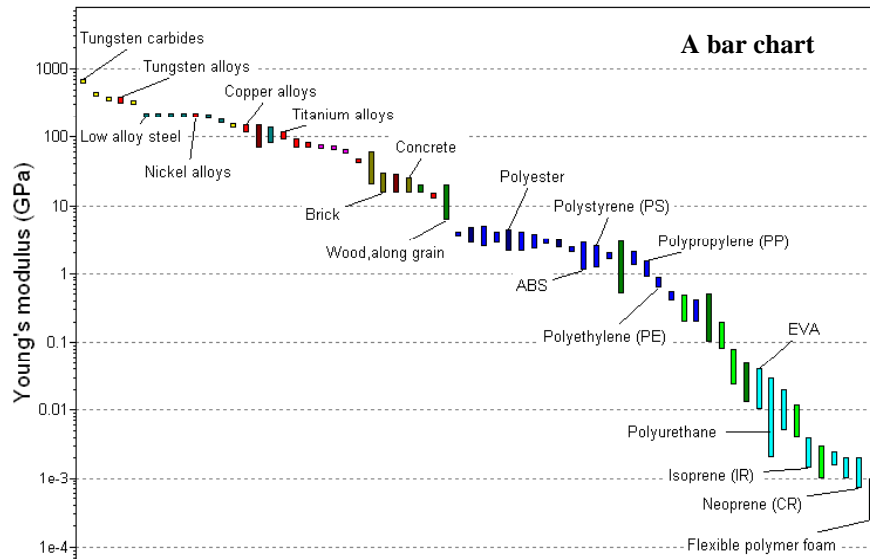
(Set y-axis to Young’s modulus; leave x-axis at <None>)
 (Click on a few materials to label them; double-click to go to their record in the Data Table)

- Make a BUBBLE CHART of YOUNG’S MODULUS (E) against DENSITY (ρ)

(Set both x-axis and y-axis; the default is a log-log plot)
 (Materials can be labeled as before – click and drag to move the labels; use DEL to delete a label.)



DELETE THE STAGE (Right click on stage and select “Delete”)



SELECTION using a LIMIT STAGE

Exercise 5. Selection using a LIMIT stage

- Find materials with :

MAX. SERVICE TEMPERATURE > 200 °C

THERMAL CONDUCTIVITY > 25 W/m.k

ELECTRICAL CONDUCTOR = GOOD INSULATOR OR INSULATOR?

(Enter the limits – minimum or maximum as appropriate – and click “Apply”)

(Results at Level 1 or 2: aluminum nitride, alumina, silicon nitride)

DELETE THE STAGE

The screenshot shows the 'Select' button highlighted in the top toolbar. Below it, the '1. Selection data' section shows 'Edu Level 2: Materials'. The '2. Selection Stages' section has 'Limit' selected. A 'Results' table is shown, and a 'Limit stage' configuration panel is open on the right, showing property limits and electrical conductor/insulator options.

1. Selection data
Edu Level 2: Materials

2. Selection Stages
Graph Limit Tree

Results	Ranking	
	X out of 95 pass	Prop 1 Prop 2
Material 1	2230	113
Material 2	2100	300
Material 3	1950	5.6
Material 4	1876	47
etc...		

A Limit stage

► Mechanical properties

▼ Thermal properties

	Min.	Max	
Maximum service temperature	200		C
Thermal conductivity	25		W/m.K
Specific heat			J/kg.K



▼ Electrical properties

Electrical conductor or insulator?

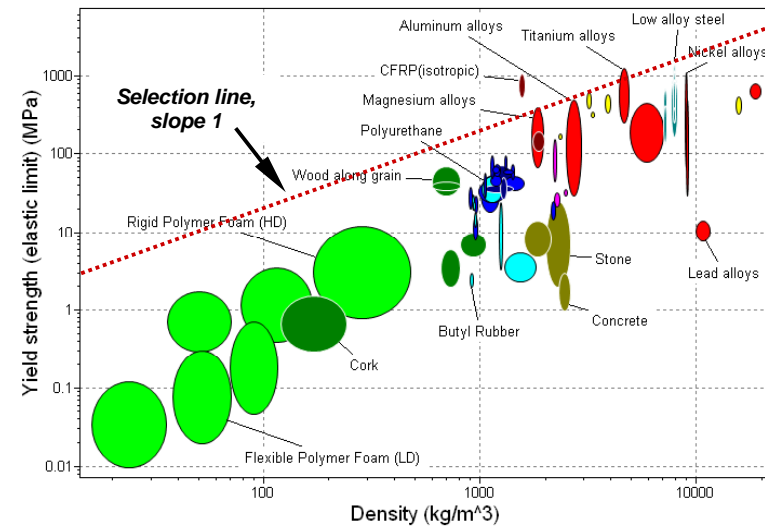
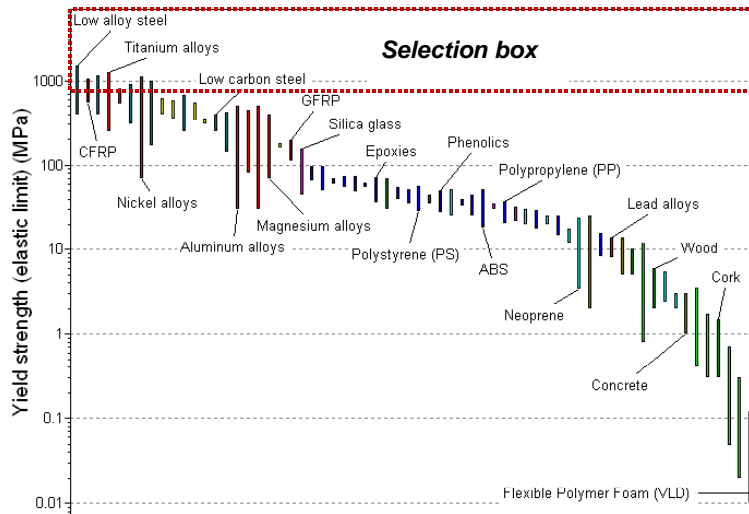
- Good conductor
- Poor conductor
- Semiconductor
- Poor insulator
- Good insulator

GRAPH SELECTION

Exercise 6 Selection with a GRAPH stage

- Make a BAR CHART of Yield strength (σ_y) (plotted on the y-axis).
- Use a BOX SELECTION  to find materials with high values of elastic limit (or strength).
(Click the box icon, then click-drag to define the box)
- Add, on the other axis, DENSITY (ρ)
(Either: highlight Stage 1 in Selection Stages, and click Edit; or double-click the axis to edit)
- Use a BOX SELECTION to find materials with high strength and low density.
- Replace the BOX with a LINE SELECTION  to find materials with high values of the “specific strength”, σ_y / ρ .
(Click the line icon, then enter slope required – 1 in this case – click the graph to position the line, click again to select the side required, i.e. above the line for high values of σ_y / ρ . Now click on the line and drag upwards, to refine the selection to just 3 materials).
(Results at Level 1 or 2: CFRP (isotropic), Titanium alloys, Magnesium alloys)

DELETE THE STAGE



2. Selection Stages

Graph Limit Tree

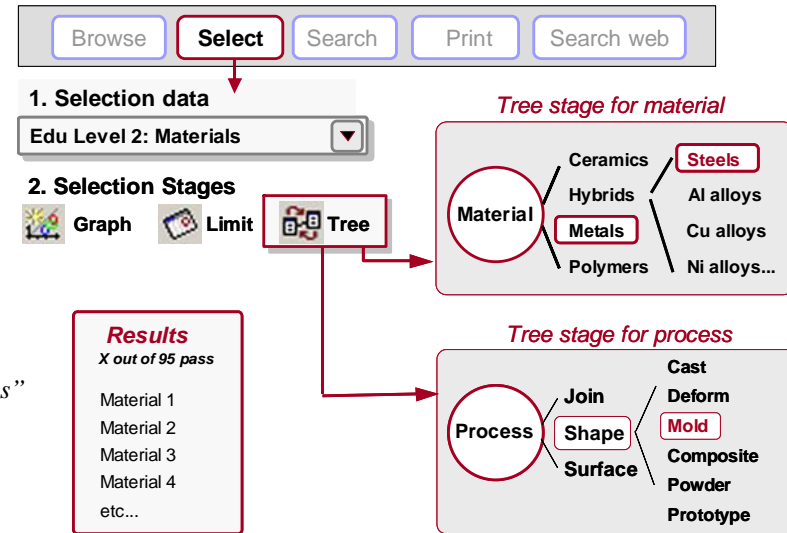
Results	Ranking
X out of 95 pass	Prop 1 Prop 2
Material 1	2230 113
Material 2	2100 300
Material 3	1950 5.6
Material 4	1876 47
etc...	

TREE SELECTION

Exercise 7. Selection with a TREE Stage

- Find MATERIALS that can be MOLDED
(In Tree Stage window, select ProcessUniverse, expand “Shaping” in the tree, select Molding, and click “Insert”, then OK)
- DELETE THE STAGE
- Find PROCESSES to join STEELS
*(First change Selection Data to select Processes: select LEVEL 2, JOINING PROCESSES.)
(Then, in Tree Stage window, select MaterialUniverse, expand “Metals and alloys” in the tree, select Ferrous, and click “Insert”, then OK)*

DELETE THE STAGE



GETTING IT ALL TOGETHER

Exercise 8. Using ALL 3 STAGES together

Change Selection data to select materials:
Select LEVEL 2, MATERIALS

Find MATERIALS that are

- DENSITY < 2000 kg/m³
- STRENGTH (Elastic limit) > 60 MPa
- THERMAL CONDUCTIVITY < 10 W/m.K
(3 entries in a Limit Stage)
- Can be THERMOFORMED
(a Tree Stage: ProcessUniverse – Shaping - Molding)
- Rank the results by PRICE
(a Graph Stage: bar chart of Price)
(On the final Graph Stage, click the “Intersect Stages” icon, like a small Venn diagram; materials failing one or more stages turn grey; label the remaining materials, which pass all stages. The RESULTS window shows the materials that pass all the stages.)

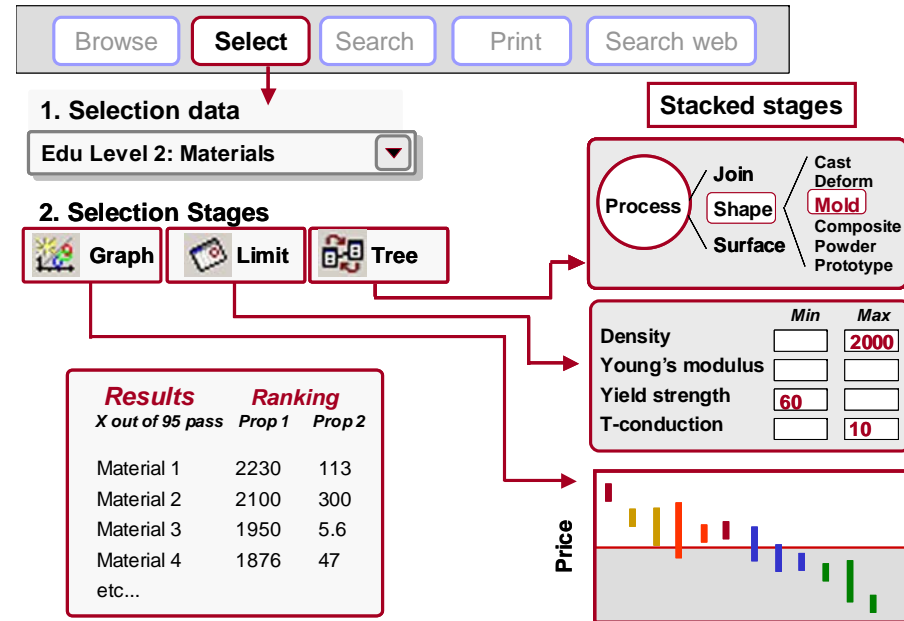
(Results, cheapest first: PET, PMMA, Acetal (POM))

Exercise 9 Finding SUPPORTING INFORMATION

(Requires Internet connection)

- With the PET record open, click on SEARCH WEB
(CES translates the material ID to strings compatible with a group of high-quality material and process information sources and delivers the hits. Some of the sources are open access, others require a subscriber-based password. The ASM source is particularly recommended.)

DELETE THE STAGE



PROCESS SELECTION

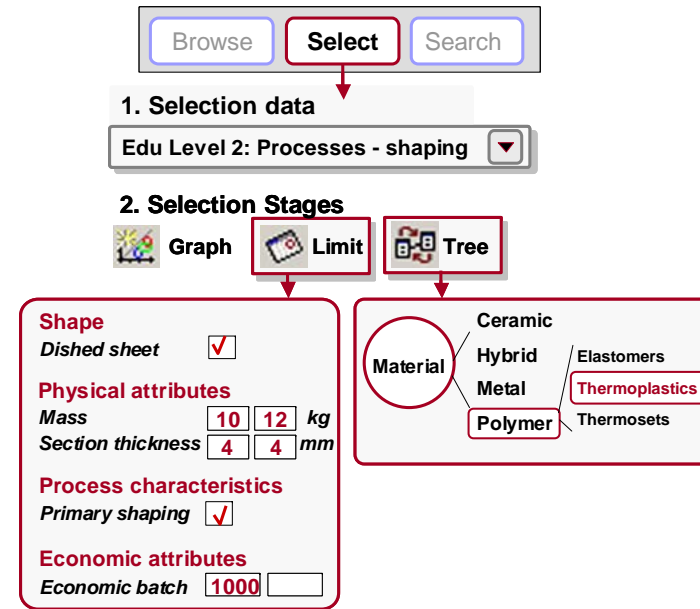
Exercise 10 Selecting PROCESSES

Change Selection data to select processes:
Select LEVEL 2, SHAPING PROCESSES

Find PRIMARY SHAPING PROCESSES to make a component with:

- SHAPE = Dished sheet
- MASS = 10 – 12 kg
- SECTION THICKNESS = 4 mm
- ECONOMIC BATCH SIZE > 1000
(3 entries in a Limit Stage)
- Made of a THERMOPLASTIC,
(a Tree Stage: MaterialUniverse – Polymer – Thermoplastics)

(Result: manual compression molding, rotational molding, thermoforming)



SAVING, COPYING, and REPORT WRITING

Exercise 11. Saving Selection Stages as a PROJECT

- SAVE the project – exactly as if saving a file in Word
(give it a filename and directory location; CES project files have the extension “.ces”).

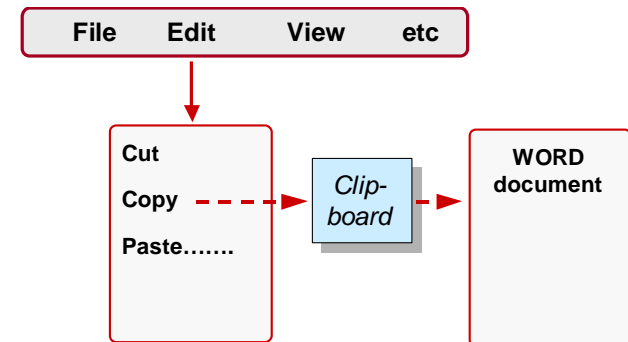
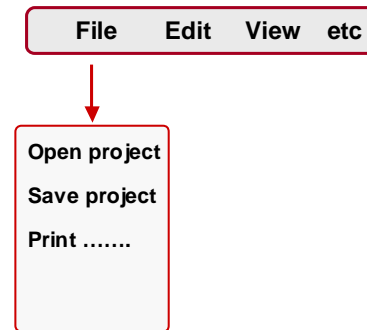
Exercise 12. COPYING CES OUTPUT into a Report

Charts, Records and Results lists may be copied (CTRL-C) and pasted (CTRL-V) into Word.

- Display a chart, click on it, then COPY and PASTE it into a WORD document
- Double click a selected material in the Results window to display its record, click on the record, then COPY and PASTE it.
- Click on the Results window, then COPY and PASTE it.
- Try editing the document

(The records in Exercise 3 and the selection charts on Exercises 4 and 6 were made in this way.)

(Warning: There is a problem with WORD 2000: the image in the record is not transferred with the text. The problem is overcome by copying the image and pasting it separately into the WORD document as a DEVICE INDEPENDENT BITMAP.)



ADVANCED METHODS

Exercise 13. Plotting FUNCTIONS OF PROPERTIES

- Make a chart with axes of specific modulus E/ρ and specific strength σ_y/ρ , where E is Young's modulus, σ_y is the elastic limit and ρ is the density.

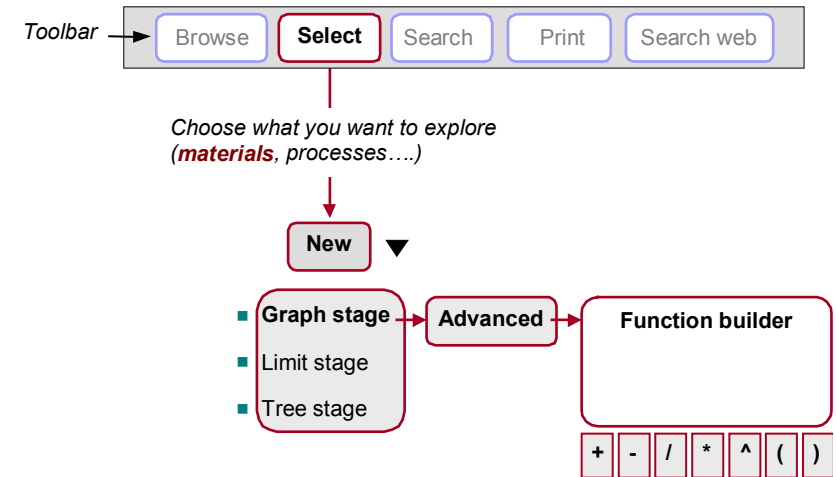
(For each axis, click *Advanced* to bring up the Function Builder. To plot, for example E/ρ :

- on *Attributes* tab, pick "Mechanical Properties" from the list, then "Young's modulus", then *Insert*;
- now click "/" from the row of function symbols;
- finally, on *Attributes* tab, pick "General Properties" – "Density" – *Insert*. Click *OK*)

- Add a limit stage to eliminate materials with fracture toughness $< 20 \text{ MPa.m}^{1/2}$
- Find the surviving material with highest values of both E/ρ and σ_y/ρ

(Return to *Graph Stage*, and click on "Intersect Stages" icon)

(Result: CFRP (isotropic))



FUNCTIONAL DATA: COST MODELLING

Set the selector to **PROCESS UNIVERSE, Level 2 SHAPING**

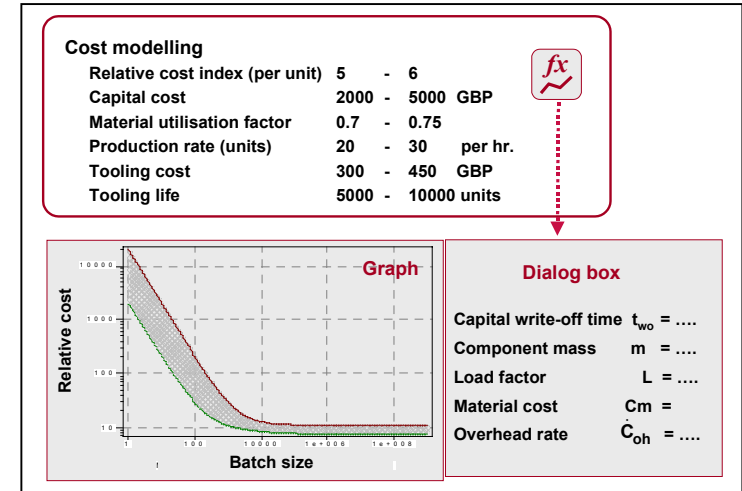
Exercise 14. Exploring COST

Component COST is estimated in CES using a “functional attribute”, i.e. for each process, a cost range is calculated depending on parameters which must be specified by the user (such as the batch size).

- Open the process record, INJECTION MOLDING, and find RELATIVE COST INDEX
- Click on the Parameters: link to open the dialog box, and enter the following:
 COMPONENT MASS = 0.1 kg.
 MATERIAL COST = £1/kg
 OVERHEAD RATE = £40 per hour.
 CAPITAL WRITE-OFF TIME = 5 years:
 LOAD FACTOR = 0.5.
- Click the graph icon, to display RELATIVE COST INDEX against BATCH SIZE.
- Repeat for COMPRESSION MOLDING, and compare the cost of making the component using these two processes, at low batch sizes and high batch sizes.

(Result: Compression Molding is cheaper at low batch sizes, Injection Molding at high batch sizes)

- Alternatively, plot RELATIVE COST INDEX for all processes (for a specified batch size), and identify these 2 processes to compare their cost.
*(Use a Graph Stage bar chart with y-axis attribute: Economic Attributes – Relative Cost Index.
 Make a Tree Stage: ProcessUniverse - Shaping – Molding, select and Insert “Compression Molding” and “Injection Molding” in turn. Click “Intersect Stages” on bar chart, and label the 2 processes)*
- Edit the batch size, to explore the relative costs of the processes.
(The axis label gives the current parameter values – double-click the axis to bring up the Stage Properties window, and click Parameters - “Edit” – enter values required)



Appendices

Toolbars in CES EduPack

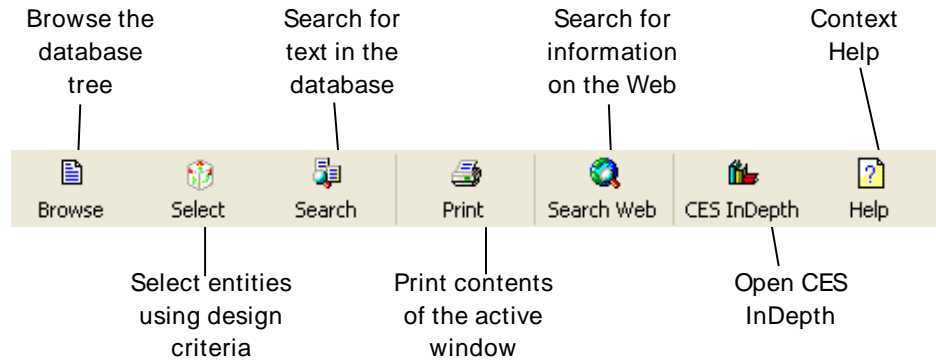


Figure A1. The Standard toolbar in CES EduPack

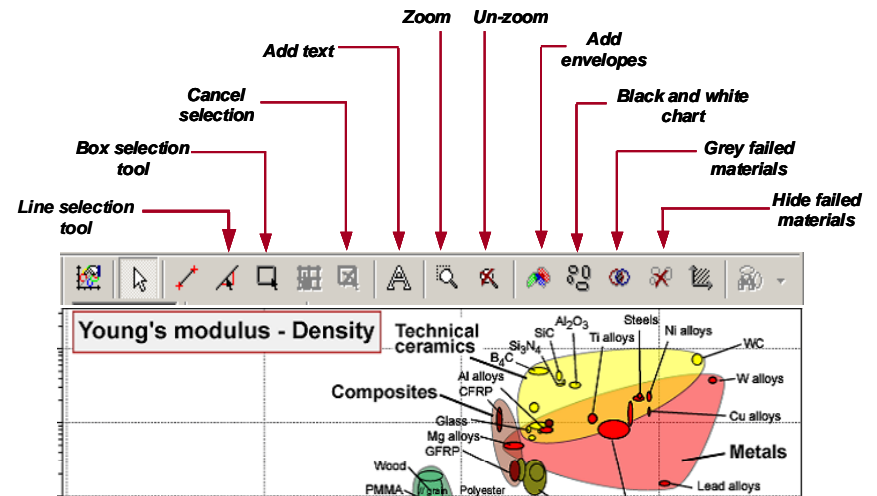


Figure A2. The Graph Stage toolbar in CES EduPack

Physical constants and conversion of units

Absolute zero temperature	-273.2°C
Acceleration due to gravity, g	9.807m/s ²
Avogadro's number, N _A	6.022 x 10 ²³
Base of natural logarithms, e	2.718
Boltzmann's constant, k	1.381 x 10 ⁻²³ J/K
Faraday's constant k	9.648 x 10 ⁴ C/mol
Gas constant, \bar{R}	8.314 J/mol/K
Planck's constant, h	6.626 x 10 ⁻³⁴ J/s
Velocity of light in vacuum, c	2.998 x 10 ⁸ m/s
Volume of perfect gas at STP	22.41 x 10 ⁻³ m ³ /mol

Angle, θ	1 rad	57.30°
Density, ρ	1 lb/ft ³	16.03 kg/m ³
Diffusion Coefficient, D	1cm ² /s	1.0 x 10 ⁻⁴ m ² /s
Energy, U	See opposite	
Force, F	1 kgf	9.807 N
	1 lbf	4.448 N
	1 dyne	1.0 x 10 ⁻⁵ N
Length, l	1 ft	304.8 mm
	1 inch	25.40 mm
	1 Å	0.1 nm
Mass, M	1 tonne	1000 kg
	1 short ton	908 kg
	1 long ton	1107 kg
	1 lb mass	0.454 kg
Power, P	See opposite	
Stress, σ	See opposite	
Specific Heat, Cp	1 cal/gal.°C	4.188 kJ/kg.°C
	Btu/lb.°F	4.187 kg/kg.°C
Stress Intensity, K _{Ic}	1 ksi $\sqrt{\text{in}}$	1.10 MN/m ^{3/2}
Surface Energy γ	1 erg/cm ²	1 mJ/m ²
Temperature, T	1°F	0.556°K
Thermal Conductivity λ	1 cal/s.cm.°C	418.8 W/m.°C
	1 Btu/h.ft.°F	1.731 W/m.°C
Volume, V	1 Imperial gall	4.546 x 10 ⁻³ m ³
	1 US gall	3.785 x 10 ⁻³ m ³
Viscosity, η	1 poise	0.1 N.s/m ²
	1 lb ft.s	0.1517 N.s/m ²

Conversion of units – stress and pressure*

	MPa	dyn/cm ²	lb.in ²	kgf/mm ²	bar	long ton/in ²
MPa	1	10 ⁷	1.45 x 10 ²	0.102	10	6.48 x 10 ⁻²
dyn/cm ²	10 ⁻⁷	1	1.45 x 10 ⁻⁵	1.02 x 10 ⁻⁸	10 ⁻⁶	6.48 x 10 ⁻⁹
lb/in ²	6.89 x 10 ⁻³	6.89 x 10 ⁴	1	703 x 10 ⁻⁴	6.89 x 10 ⁻²	4.46 x 10 ⁻⁴
kgf/mm ²	9.81	9.81 x 10 ⁷	1.42 x 10 ³	1	98.1	63.5 x 10 ⁻²
bar	0.10	10 ⁶	14.48	1.02 x 10 ⁻²	1	6.48 x 10 ⁻³
long ton/in ²	15.44	1.54 x 10 ⁸	2.24 x 10 ³	1.54	1.54 x 10 ²	1

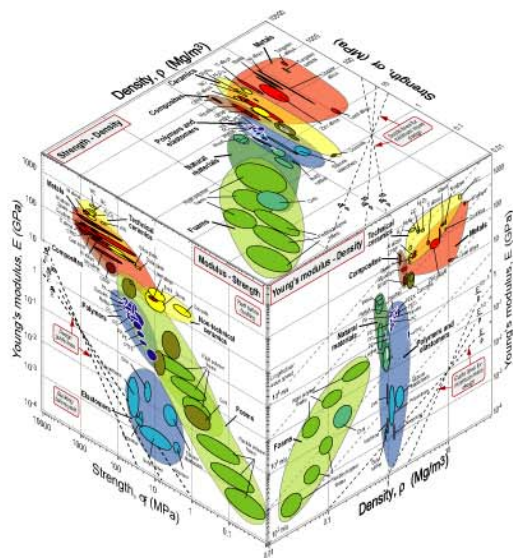
Conversion of units – energy*

	J	erg	cal	eV	Btu	ft lbf
J	1	10 ⁷	0.239	6.24 x 10 ¹⁸	9.48 x 10 ⁻⁴	0.738
erg	10 ⁻⁷	1	2.39 x 10 ⁻⁸	6.24 x 10 ¹¹	9.48 x 10 ⁻¹¹	7.38 x 10 ⁻⁸
cal	4.19	4.19 x 10 ⁷	1	2.61 x 10 ¹⁹	3.97 x 10 ⁻³	3.09
eV	1.60 x 10 ⁻¹⁹	1.60 x 10 ⁻¹²	3.38 x 10 ⁻²⁰	1	1.52 x 10 ⁻²²	1.18 x 10 ⁻¹⁹
Btu	1.06 x 10 ³	1.06 x 10 ¹⁰	2.52 x 10 ²	6.59 x 10 ²¹	1	7.78 x 10 ²
ft lbf	1.36	1.36 x 10 ⁷	0.324	8.46 x 10 ¹⁸	1.29 x 10 ⁻³	1

Conversion of units – power*

	kW (kJ/s)	erg/s	hp	ft lbf/s
kW (kJ/s)	1	10 ⁻¹⁰	1.34	7.38 x 10 ²
erg/s	10 ⁻¹⁰	1	1.34 x 10 ⁻¹⁰	7.38 x 10 ⁻⁸
hp	7.46 x 10 ⁻¹	7.46 x 10 ⁹	1	15.50 X 10 ²
Ft lbf/s	1.36 X 10 ⁻³	1.36 X 10 ⁷	1.82 X 10 ⁻³	1

* To convert row unit to column unit, multiply by the number a the column row intersection, thus 1MPa = 1 bar



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